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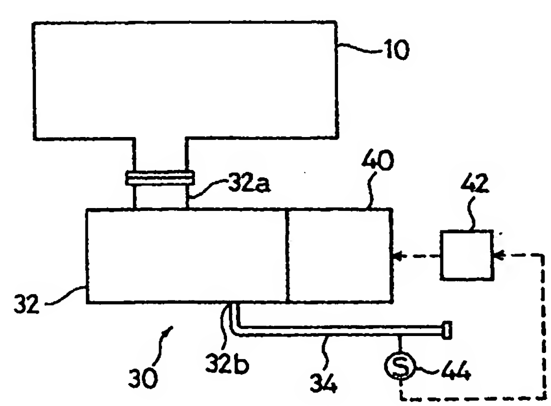
(54) DEVICE AND METHOD FOR EVACUATION

(57) The present invention is related to an apparatus for and a method of evacuating a vacuum chamber (process chamber) or the like of a semiconductor fabrication facility, for example. The evacuating apparatus has a vacuum chamber (10) to be evacuated, a discharge pipe (34) connecting the vacuum chamber to an atmospheric port, a vacuum pump (32) connected to the discharge pipe (34) and operable at a variable rotational speed, and a controller (42) for controlling the rotational speed of the vacuum pump (32).

F I G. 1



EP 1 081 380 A1

Description

Technical Field

[0001] The present invention relates to an apparatus for and a method of evacuating a vacuum chamber (process chamber) of, for example, a semiconductor fabrication facility or the like.

Background Art

[0002] FIG. 7 of the accompanying drawings shows an evacuating path for evacuating a vacuum chamber 10, which is used in an etching apparatus, a chemical vapor deposition apparatus (CVD), or the like for a semiconductor fabrication process. To the vacuum chamber 10, there is connected an inlet port 14a of a vacuum pump 14 of an evacuating system 12. The vacuum pump 14 has an outlet port 14b connected to a discharge pipe 16. The vacuum pump 14 serves to increase the pressure of a process gas discharged from the vacuum chamber 10 to the atmospheric pressure. The vacuum pump 14 has conventionally been in the form of an oil rotary pump, but primarily comprises a dry pump at present.

[0003] If the vacuum level required by the vacuum chamber 10 is higher than the vacuum level that can be acquired by the vacuum pump 14, then an ultrahigh vacuum pump such as a turbo-molecular pump or the like may be positioned upstream of the vacuum pump. If the process gas is of a type that cannot be discharged directly into the atmosphere, then a discharge gas processing facility is connected to the discharge pipe 16.

[0004] Heretofore, it has generally been customary to use an induction motor rotatable at a rated rotational speed as a motor 20 of the vacuum pump 14 of the evacuating system 12. In order to allow a large amount of gas to evacuate smoothly when the pump is started or when the atmosphere air is introduced in the chamber, and also to keep the back pressure on the vacuum pump 14 in an allowable range, the discharge pipe 16 has had an inside diameter of about 40 mm if the process gas is discharged at a rate of about 2000 L/min, for example.

[0005] Usually, the vacuum chamber of the semiconductor fabrication facility is placed in a clean room, and hence the discharge pipe is occasionally laid over a long distance in the clean room up to the external space. If the discharge pipe is large in diameter, then it will take up a costly space and have its layout limited due to interference with other component devices of the semiconductor fabrication facility. If the discharge pipe is small in diameter, then it causes an undue increase in the back pressure on the vacuum pump at the time a large amount of gas flows when the pump is started or the atmosphere air is introduced, with the result that the vacuum pump tends to fail to operate due to an excessive load. Therefore, there is a certain limitation to make the reduce of the diameter of the discharge pipe.

Disclosure of Invention

[0006] The present invention has been made in view of the above drawbacks. It is an object of the present invention to provide an apparatus for and a method of evacuating a vacuum chamber with an evacuating system which includes a discharge pipe having a reduced diameter for space saving, and which operates stably by avoiding overloaded operation.

[0007] According to an invention recited in claim 1, an apparatus for evacuating a vacuum chamber comprises a vacuum chamber to be evacuated, a discharge pipe connecting the vacuum chamber to an atmospheric port, a vacuum pump connected to the discharge pipe and operable at a variable rotational speed, and a controller for controlling the rotational speed of the vacuum pump. Even when a large amount of gas is discharged at the time the vacuum pump is started, the back pressure on the vacuum pump is controlled so as not to exceed a certain value. Thus, the evacuating apparatus can operate stably. The discharge pipe whose diameter is smaller than required by the evacuating capability can be used, and it is possible to effectively utilize the space in an expensive clean room.

[0008] According to an invention recited in claim 2, the apparatus according to claim 1 further comprises a back pressure sensor connected to a discharge port of the vacuum pump, for detecting a back pressure on the vacuum pump, wherein the controller controls the rotational speed of the vacuum pump based on a detected output from the back pressure sensor. Therefore, the back pressure can be controlled accurately at all times to operate the evacuating apparatus stably.

[0009] According to an invention recited in claim 3, in the apparatus according to claim 2, herein the controller controls the rotational speed of the vacuum pump to keep the detected output from the back pressure sensor in a predetermined target range.

[0010] According to an invention recited in claim 4, in the apparatus according to claim 2, the controller controls the rotational speed of the vacuum pump to prevent the detected output of the back pressure sensor from exceeding a predetermined target value.

[0011] According to an invention recited in claim 5, the apparatus according to claim 2 further comprises a booster pump connected to the discharge pipe in series with the vacuum pump, wherein the controller controls to start the booster pump when the vacuum pump has an insufficient evacuating capability, based on the detected output from the back pressure sensor. Therefore, evacuating apparatus is thus capable of handling a large evacuating load while saving energy.

[0012] According to an invention recited in claim 6, in the apparatus according to claim 1, the controller controls the rotational speed of the vacuum pump accord-

ing to a previously inputted pattern of changes in the rotational speed. The back pressure can thus be controlled with a simple apparatus arrangement, and the evacuating apparatus can start up stably.

[0013] According to an invention recited in claim 7, in the apparatus according to claim 1, the discharge pipe has a conductance smaller than the evacuating capability of the vacuum pump. Therefore, the space required for piping is reduced, and the space in an expensive clean room can be effectively utilized. The pipe and the apparatus are easily joined to each other.

[0014] According to an invention recited in claim 8, there is provided a method of evacuating a vacuum chamber through a discharge pipe with a vacuum pump having a variable rotational speed, which comprises the steps of detecting a back pressure on the vacuum pump, and controlling the rotational speed of the vacuum pump based on the detected back pressure on the vacuum pump.

[0015] According to an invention recited in claim 9, in the method according to claim 8, a booster pump is connected to the discharge pipe in series with the vacuum pump, and the method further comprises the step of starting the booster pump when the vacuum pump has an insufficient evacuating capability, based on the detected back pressure on the vacuum pump.

[0016] According to an invention recited in claim 10, the method according to claim 8 further comprises the step of controlling the rotational speed of the vacuum pump according to a previously inputted pattern of changes in the rotational speed in an initial period of evacuating the vacuum pump.

[0017] According to an invention recited in claim 11, there is provided a method of evacuating a vacuum chamber through a discharge pipe with a vacuum pump having a variable rotational speed, which comprises the step of controlling the rotational speed of the vacuum pump according to a previously inputted pattern of changes in the rotational speed in an initial period of evacuating the vacuum pump.

[0018] According to an invention recited in claim 12, in the method according to claim 11, the rotational speed increases at a rate selected to keep an initial peak of the back pressure in evacuating the vacuum chamber, equal to or below a predetermined value.

[0019] According to an invention recited in claim 13, in the method according to claim 11, the rotational speed increases stepwise.

Brief Description of the Drawings

[0020]

FIG. 1 is a view showing an evacuating apparatus according to an embodiment of the present invention;

FIG. 2 is a graph showing how the rotational speed of a vacuum pump varies with time in a method of operating the vacuum pump according to a first embodiment of the present invention, in comparison with a conventional example;

FIG. 3 is a graph showing how the rotational speed and back pressure of a vacuum pump varies with time in a method of operating the vacuum pump according to a second embodiment of the present invention, in comparison with a conventional example;

FIG. 4 is a graph showing how the rotational speed and back pressure of a vacuum pump varies with time in a method of operating the vacuum pump according to a third embodiment of the present invention, in comparison with a conventional example;

FIG. 5 is a view showing an evacuating apparatus according to another embodiment of the present invention;

FIG. 6 is a graph showing how the rotational speed and back pressure of a vacuum pump varies with time in a method of operating the vacuum pump according to a fifth embodiment of the present invention; and

FIG. 7 is a view showing a conventional evacuating apparatus.

Best Mode for Carrying Out the Invention

[0021] Embodiments of the present invention will be described below with reference to the drawings. FIG. 1 shows an evacuating system 30 for evacuating a vacuum chamber 10, which is used in an etching apparatus, a chemical vapor deposition apparatus (CVD), or the like for a semiconductor fabrication process performed thereby. The vacuum chamber 10 is connected to an inlet port 32a of a vacuum pump 32, which has an outlet port 32b connected to a discharge pipe 34.

[0022] The vacuum pump 32 comprises a so-called dry pump which does not use a lubricant in a gas passage. The vacuum pump 32 is operated by a motor 40 comprising a DC motor, particularly, a brushless DC motor, having a rotational speed controller 42 which employs an inverter (frequency converting circuit), for example. The discharge pipe 34 has a diameter smaller than the diameter of the conventional discharge pipe 16 shown in FIG. 7. For example, if the gas is discharged at a rate of about 2000 L(liter)/min., then the discharge pipe 34 has an inside diameter of about 10 mm. The inside diameter of the discharge pipe 34 is determined such that the conductance is of a certain value, in view of the length of the discharge pipe 34.

[0023] A back pressure sensor 44 for detecting the pressure in the discharge pipe 34, i.e., the back pressure on the vacuum pump 32, is disposed near the outlet port of the discharge pipe 34. An output signal from the back pressure sensor 44 is applied to the rotational speed controller 42 of the motor 40.

[0024] A method of operating the vacuum pump 32

for starting the vacuum pump 32 will be described below with reference to FIG. 2. In this embodiment, the rotational speed of the vacuum pump 32 is controlled to keep the back pressure on the vacuum pump 32 at a predetermined value P_0. Specifically, when the detected back pressure of the vacuum pump 32 reaches $P_0 + \alpha$, the rotational speed controller 42 lowers the rotational speed of the motor 40, and when the detected back pressure of the vacuum pump 32 becomes lower than $P_0 - \alpha$, the rotational speed controller 42 raises the rotational speed of the motor 40. As a result, as indicated by the broken-line curve in FIG. 2, the back pressure is kept substantially at the predetermined value P_0, allowing the vacuum pump 32 to operate stably though a prolonged time is required. After elapse of a predetermined time, the back pressure drops below the predetermined value P_0, and the vacuum pump 32 enters a steady mode of operation.

[0025] In the above embodiment, the vacuum pump 32 is controlled in a feedback loop using the back pressure sensor 44. Another embodiment which performs a simpler sequence control mode will be described below with reference to FIG. 3. In this embodiment, the stationary installation of the back pressure sensor 44 is not required. A time-dependent change in the rotational speed of the vacuum pump 32 at the time it is started is inputted in advance to the rotational speed controller 42. In FIG. 3, such a time-dependent change is represented by a broken-line curve L_0 of a constant low gradient which reaches a steady rotational speed N_0 in a longer time T_0 than a time T_1 with the conventional pump. After the time T_0, the vacuum pump 32 keeps the steady rotational speed N_0.

[0026] In FIG. 3, a change in the back pressure on the vacuum pump 32 is represented by a broken-line curve L_2. The change in the back pressure represented by the broken-line curve L_2 has an initial peak value P_0 smaller than the peak value of the conventional back pressure whose change is represented by a curve L_3 when the rotational speed changes according to a solid-line curve L_1. The gradient N_0/T_0 of the rotational speed change curve L_0 is determined experimentally or calculated from past experimental data depending on the capability of the vacuum pump 32, the volume, of the vacuum chamber 10, and the conductance of the discharge pipe 34, so that the vacuum pump 32 can achieve a given evacuating capability insofar as the peak value P_0 does not pose an excessive load on the motor which actuates the vacuum pump 32.

[0027] In this embodiment, since a complex control process such as the feedback control process based on the back pressure sensor is not carried out, no back pressure sensor is required, and the same advantages as those of the preceding embodiment can be achieved with a simpler arrangement. Gradient settings may be selected depending on changes in conditions such as the capability of the vacuum pump 32, the volume of the vacuum chamber 10, and the conductance of the discharge pipe 34. In the embodiment shown in FIG. 3, the rotational speed of the motor increases linearly. However, the rotational speed of the motor may increase stepwise as shown in FIG. 4.

[0028] FIG. 5 shows another embodiment of the present invention. In the embodiment shown in FIG. 5, a booster pump 50 is disposed upstream of the vacuum pump (main pump) 32 in the discharge path. The pumps 32, 50 are actuated by respective motors 40, 46, each of which comprises a brushless DC motor having a rotational speed controller 42 which employs an inverter. As with the previous embodiment, the discharge pipe 34 has a small diameter, and the back pressure sensor 44 is disposed near the outlet port of the discharge pipe 34 for the control of the rotational speed of the main pump based on the output of the back pressure sensor 44.

[0029] A method of controlling the evacuating apparatus according to the embodiment shown in FIG. 5 will be described below with reference to FIG. 6. In this embodiment, a target range for the back pressure is kept between a lower limit P_1 and an upper limit P_2 in order to discharge the gas stably and not to apply an excessive load to the motors 40, 46.

[0030] When a discharge process is started, a large amount of gas is discharged, tending to increase the back pressure, as described above. Therefore, a command is applied to start only the main pump 32 at a minimum rotational speed (step 1). The back pressure rises up to an initial peak value that is determined depending on the volume and initial pressure of the vacuum chamber 10, which is to be evacuated, and the evacuating capability at the minimum rotational speed of the main pump 32 (step 2). Then, the back pressure begins to descend. The vacuum chamber 10 is evacuated at the minimum rotational speed of the main pump 32 until the back pressure descends to and below the lower limit P_1 (step 3).

[0031] When the back pressure falls to and below the lower limit P_1, the rotational speed of the main pump 32 is increased at a constant pitch (steps 4, 4'). When the back pressure rises beyond the lower limit P_1 and enters the target range, the main pump 32 is kept at the rotational speed that has been reached (steps 5, 5'). In this manner, if the volume of the vacuum chamber 10 and the evacuating capability of the main pump 32 balance each other, the rotational speed of the main pump 32 is controlled to adjust the back pressure at around the lower limit P_1, so that the evacuating apparatus can continuously operate stably.

[0032] When the amount of gas produced by the vacuum chamber increases, the volume of the vacuum chamber 10 and the evacuating capability of the main pump 32 are brought out of balance with each other. At this time, even if a command is applied to increase the rotational speed of the main pump 32, the main pump 32 fails to keep up with the command, or the back pressure fails to increase. In this case, a timer or the like is used to detect the back pressure that is continuously

equal to or below the lower limit P_1, and a command is given to start the booster pump 50 at a rated rotational speed (step 6). In this manner, if the evacuating load on the vacuum chamber 10 is relatively large in balance with the sum of the evacuating capabilities of the main pump 32 and the booster pump 50, then the evacuating apparatus can continuously operate stably (step 7).

[0033] If the back pressure increases beyond the upper limit P_2 when the main pump 32 and the booster pump 50 are operated at their rated rotational speeds, then the booster pump 50 is shut down, and only the main pump 32 is operated (step 8). Therefore, the booster pump 50 is turned on or off depending on the back pressure.

[0034] In the above embodiment, the booster pump 50 may be of the variable speed type and may be controlled in the same fashion as with the main pump 32 in the preceding embodiment to adjust the back pressure at around the lower limit P_1. Alternatively, the booster pump 50 may be operated at the rated rotational speed, whereas the rotational speed of the main pump 32 may be controlled. If the main pump 32 has a lower minimum rated rotational speed, then the initial stage control process illustrated in FIG. 2 or 4 may be performed for the main pump 32.

[0035] In this embodiment, if the piping system suffers leakage for some reason, then the main pump 32 and the booster pump 50 may be prevented from being simultaneously operated to avoid a meaningless continuous evacuating operation. Since the back pressure on the pump does not exceed a predetermined value, the temperature of the pump is prevented from unduly increasing due to an excessive increase in the back pressure, so that the pump can operate stably.

[0036] For the same reasons, it is not necessary to provide a jacket for passing a cooling medium such as water around the pump casing to directly cool the pump casing, but a partial cooling system in the form of a conventional manifold cooler may be employed. Since no direct cooling system is employed, the temperature in the pump is not excessively lowered. Therefore, the evacuating apparatus is applicable to a process where reaction products are likely to occur.

[0037] According to the present invention, as described above, even when a large amount of gas is discharged at the time the vacuum pump is started, the back pressure on the vacuum pump is controlled so as not to exceed a certain value. The booster pump may be added which is started only when the evacuating load is increased in the process of operating the evacuating apparatus. Thus, the evacuating apparatus can operate stably while saving energy. Even though the diameter of the discharge pipe is small, the evacuating apparatus can operate stably without by avoiding overloaded operation. By using the discharge pipe whose diameter is smaller than required by the evacuating capability, it is possible to effectively utilize the space in an expensive clean room.

Industrial Applicability

[0038] The present invention is useful as an apparatus for and a method of evacuating a vacuum chamber (process chamber) or the like of a processing apparatus such as an etching apparatus, a chemical vapor deposition apparatus (CVD), or the like that is used in a semiconductor fabrication process.

Claims

1. An apparatus for evacuating a vacuum chamber, comprising:

   a vacuum chamber to be evacuated;
   a discharge pipe connecting said vacuum chamber to an atmospheric port;
   a vacuum pump connected to said discharge pipe and operable at a variable rotational speed; and
   a controller for controlling the rotational speed of said vacuum pump.

2. An apparatus according to claim 1, further comprising:

   a back pressure sensor connected to a discharge port of said vacuum pump for detecting a back pressure on the vacuum pump, wherein said controller controls the rotational speed of said vacuum pump based on a detected output from said back pressure sensor.

3. An apparatus according to claim 2, wherein said controller controls the rotational speed of said vacuum pump to keep the detected output from said back pressure sensor in a predetermined target range.

4. An apparatus according to claim 2, wherein said controller controls the rotational speed of said vacuum pump to prevent the detected output of said back pressure sensor from exceeding a predetermined target value.

5. An apparatus according to claim 2, further comprising:

   a booster pump connected to said discharge pipe in series with said vacuum pump, wherein said controller controls to start said booster pump when said vacuum pump has an insufficient evacuating capability, based on the detected output from said back pressure sensor.

6. An apparatus according to claim 1, wherein said controller controls the rotational speed of said vac-

uum pump according to a previously inputted pattern of changes in the rotational speed.

7. An apparatus according to claim 1, wherein said discharge pipe has a conductance smaller than the evacuating capability of said vacuum pump.

8. A method of evacuating a vacuum chamber through a discharge pipe with a vacuum pump having a variable rotational speed, comprising:

   detecting a back pressure on said vacuum pump; and
   controlling the rotational speed of said vacuum pump based on the detected back pressure on said vacuum pump.

9. A method according to claim 8, wherein a booster pump is connected to said discharge pipe in series with said vacuum pump, further comprising:

   starting said booster pump when said vacuum pump has an insufficient evacuating capability, based on the detected back pressure on said vacuum pump.

10. A method according to claim 8, further comprising:

   controlling the rotational speed of said vacuum pump according to a previously inputted pattern of changes in the rotational speed in an initial period of evacuating the vacuum pump.

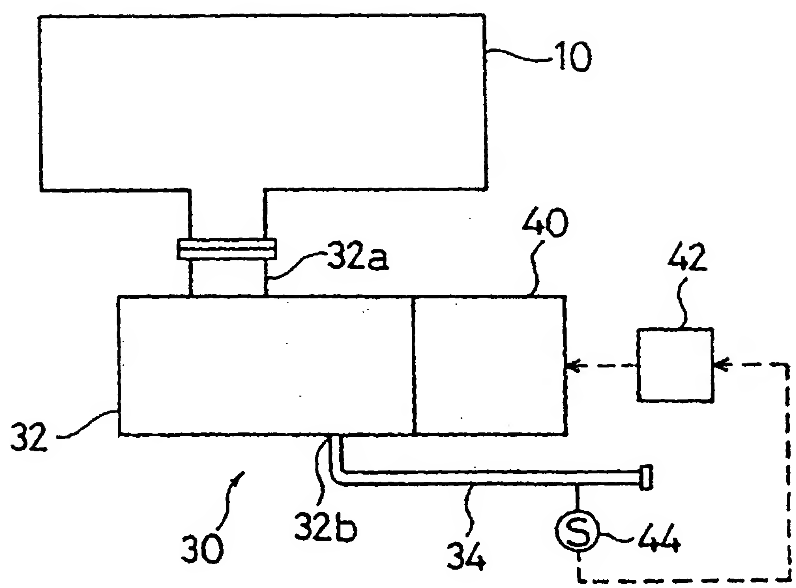
11. A method of evacuating a vacuum chamber through a discharge pipe with a vacuum pump having a variable rotational speed, comprising:

   controlling the rotational speed of said vacuum pump according to a previously inputted pattern of changes in the rotational speed in an initial period of evacuating the vacuum chamber.

12. A method according to claim 11, wherein the rotational speed increases at a rate selected to keep an initial peak of the back pressure in evacuating the vacuum chamber, equal to or below a predetermined value.

13. A method according to claim 11, wherein the rotational speed increases stepwise.

F I G. 1



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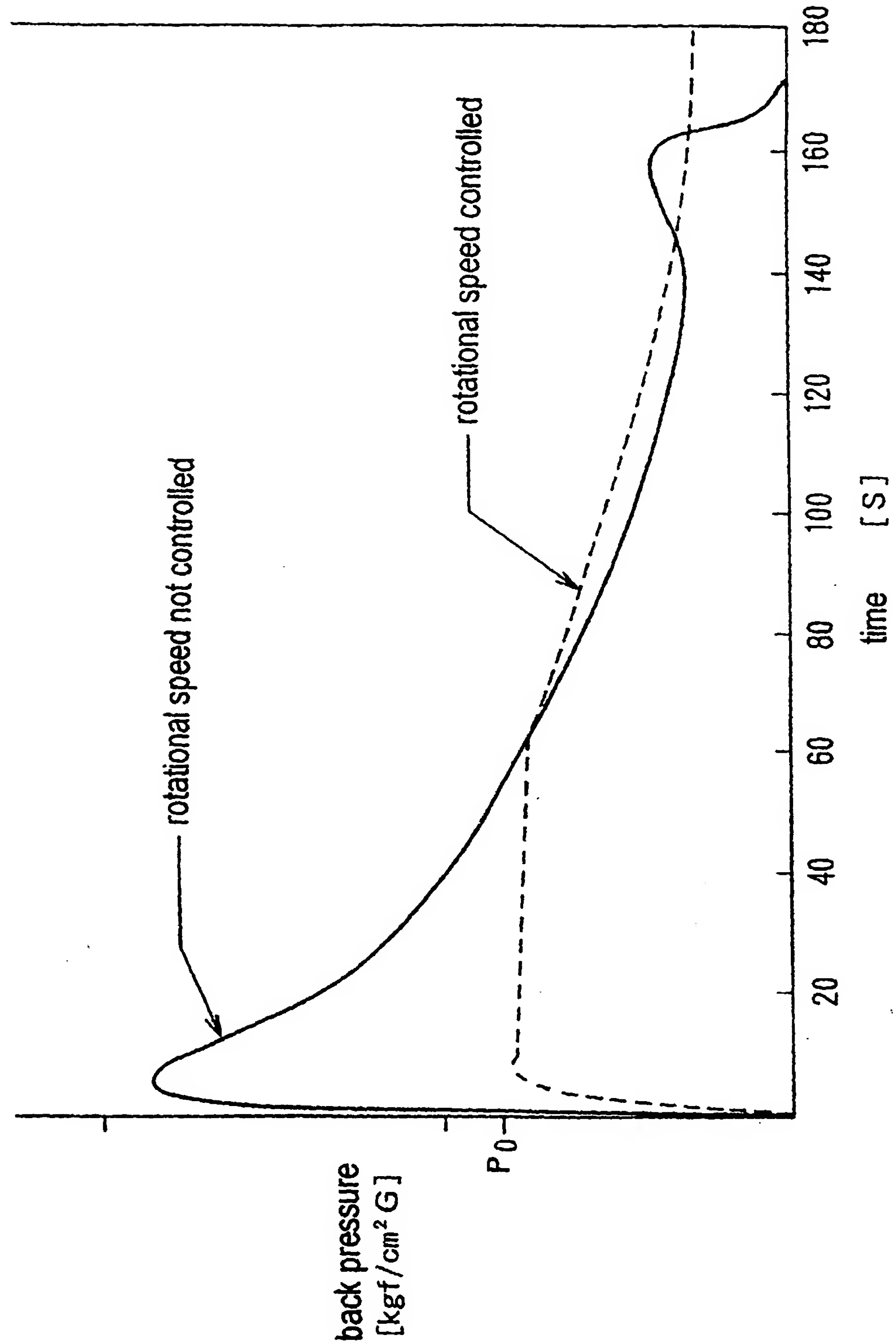
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rotational speed controlled
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P0
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time
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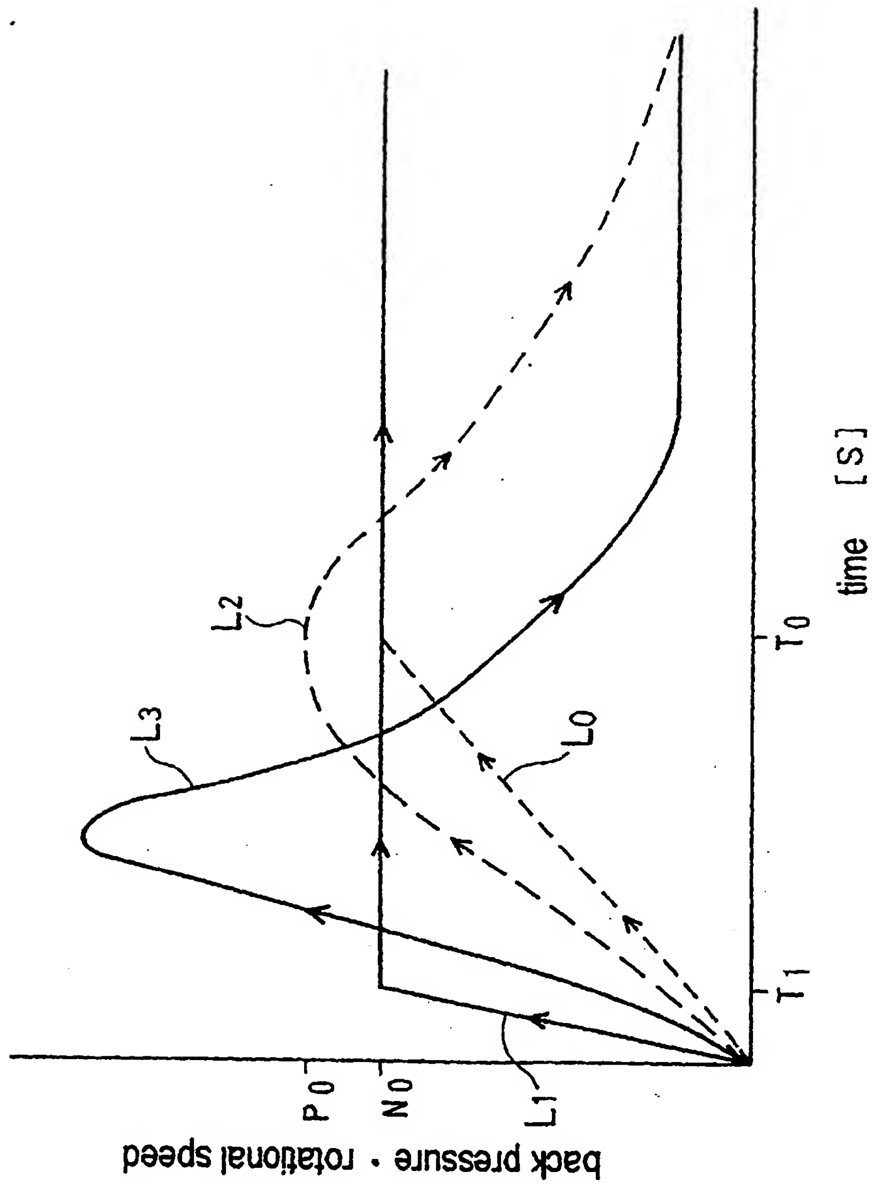
F I G. 3



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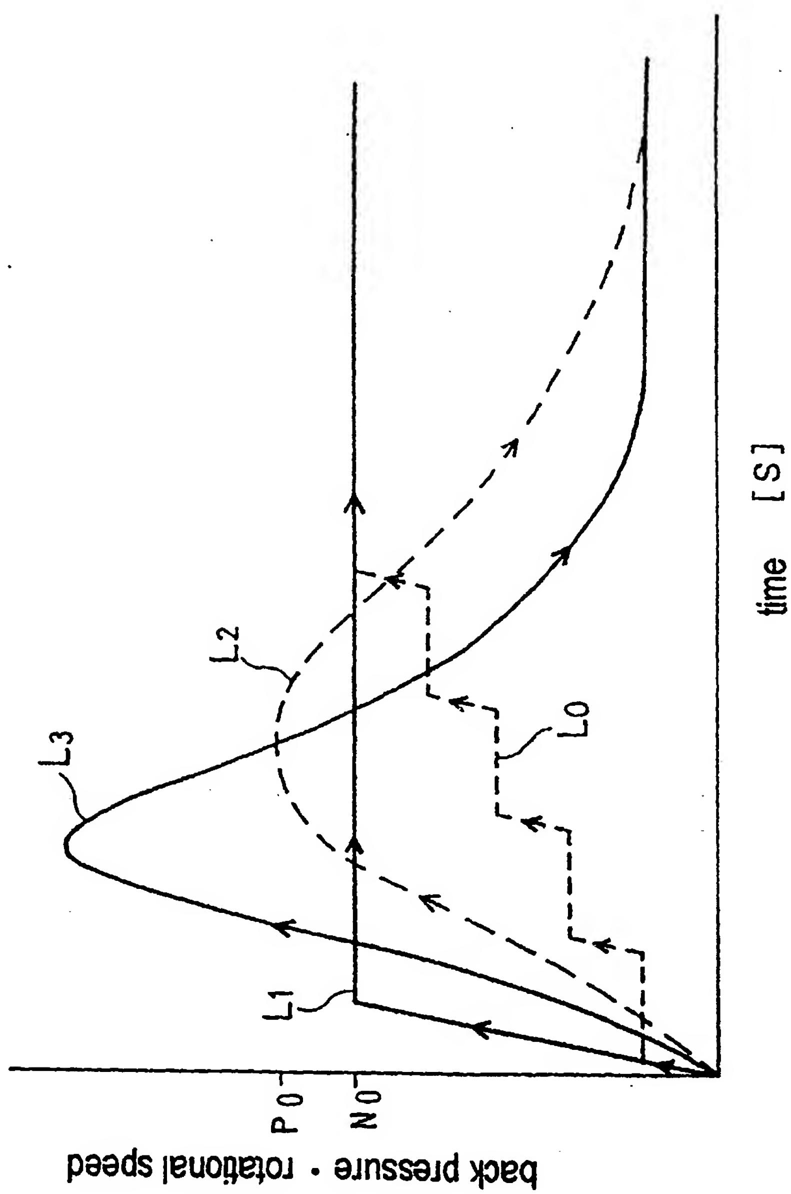

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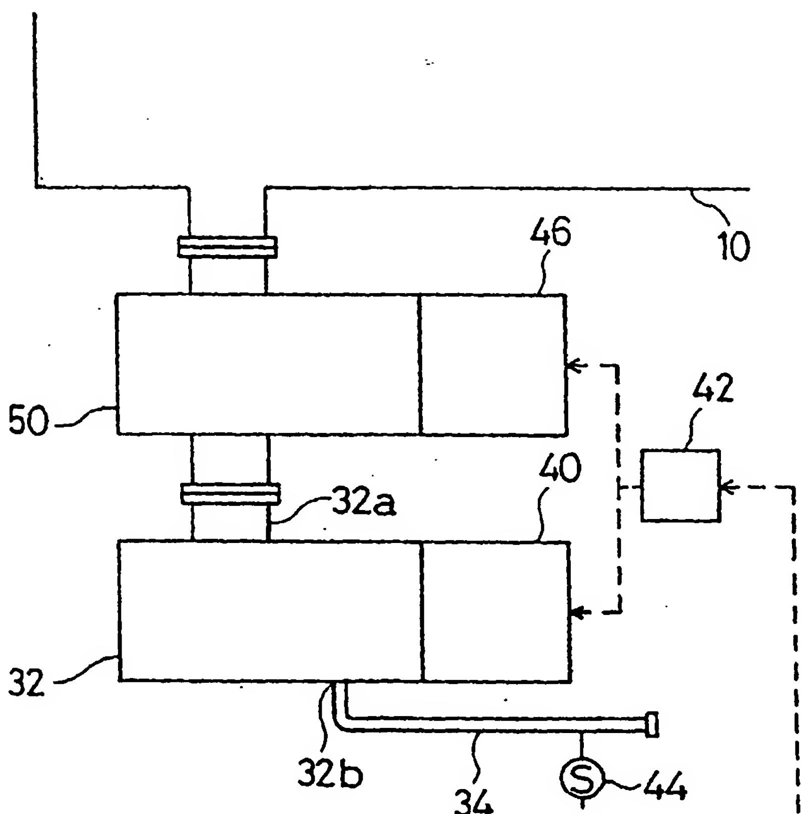


F I G. 6

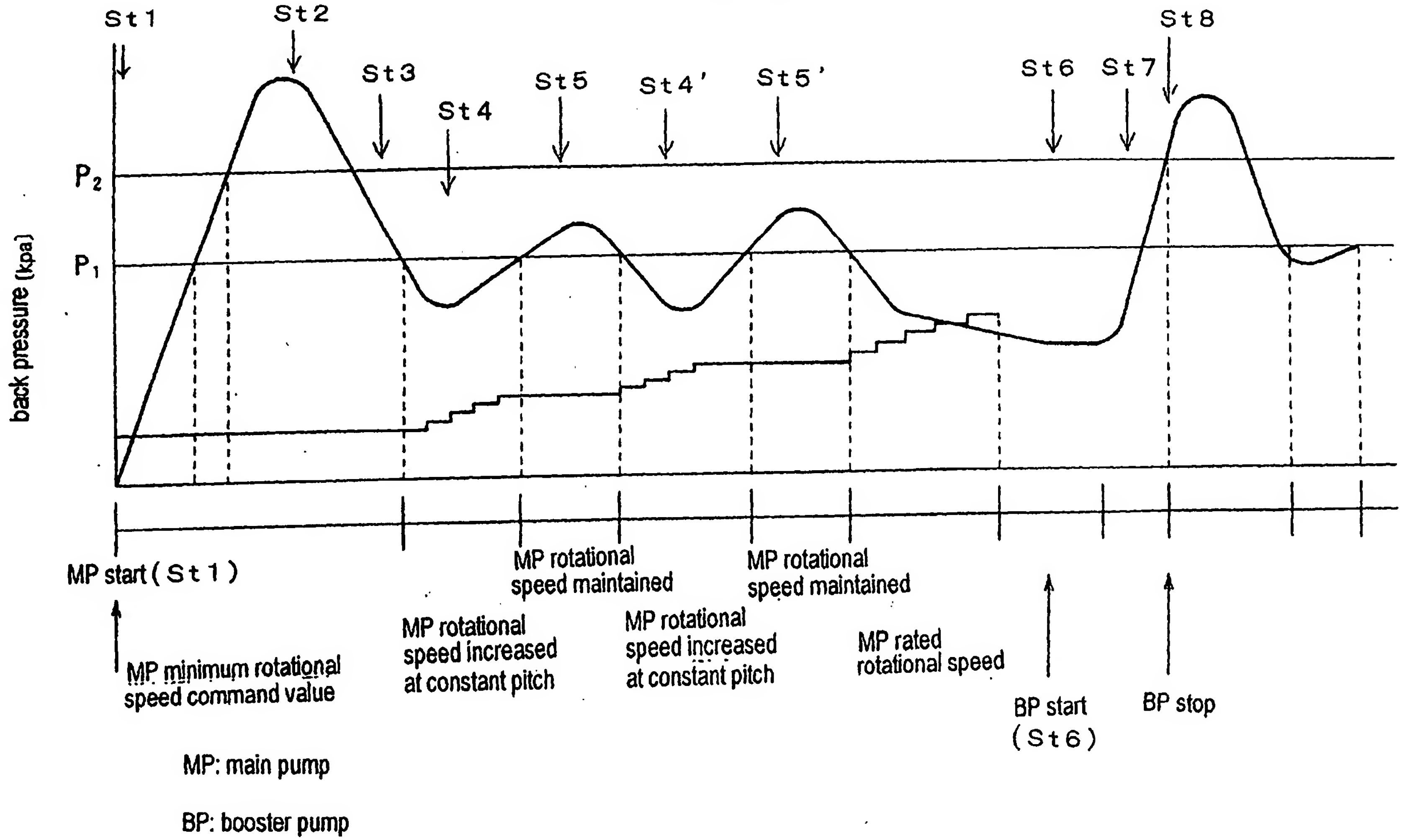
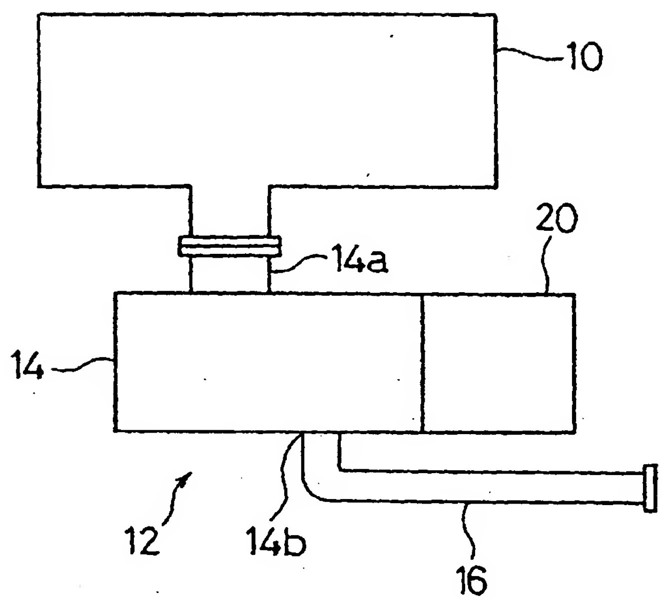

St1
St2
St3
St4
St5
St4'
St5'
St6
St7
St8
P_2
P_1
back pressure (kpa)
MP start (St1)
MP minimum rotational speed command value
MP rotational speed increased at constant pitch
MP rotational speed maintained
MP rotational speed increased at constant pitch
MP rotational speed maintained
MP rated rotational speed
BP start (St6)
BP stop
MP: main pump
BP: booster pump

FIG. 7



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP99/02645

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[6] F04B49/06, F04B37/16

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[6] F04B49/00-51/00, F04B25/00-37/20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1926-1996 Toroku Jitsuyo Shinan Koho 1994-1999
Kokai Jitsuyo Shinan Koho 1971-1995 Jitsuyo Shinan Toroku Koho 1996-1999

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 9-317641, A (Daikin Industries,Ltd.), 9 December, 1997 (09. 12. 97) (Family: none)	1-13
Y	JP, 5-195984, A (NEC Yamagata Ltd.), 6 August, 1993 (06. 08. 93) (Family: none)	1-13
Y	JP, 2-42186, A (The BOC Group,Inc.), 13 February, 1990 (13. 02. 90) & US, 4850806, A & EP, 343914, B1	5, 9
Y	JP, 1-106980, A (Alcatel Cit), 24 April, 1989 (24. 04. 89) & FR, 2621141, A1 & EP, 308846, B1	5, 9
Y	JP, 6-311778, A (Toshiba Corp.), 4 November, 1994 (04. 11. 94) (Family: none)	6, 10, 11
Y	JP, 3-152350, A (Hitachi,Ltd.), 28 June, 1991 (28. 06. 91) (Family: none)	13

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 July, 1999 (29. 07. 99)	10 August, 1999 (10. 08. 99)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP99/02645

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 8-319946, A (Japan Atomic Energy Research Institute), 3 December, 1996 (03. 12. 96) (Family: none)	7

Form PCT/ISA/210 (continuation of second sheet) (July 1992)